DESIGN & DEVELOP AUTOMATIC BATTERY CYCLIC TESTER

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ABSTRACT

Environmental concern due to fuel combustion from conventional automobile vehicles has lead to the development of Hybrid Electric Vehicle (HEV). Crucial part of Electric Vehicles (EV) is the battery life that presently limiting the realization of economically viable EV since the battery provides power to the EV.

In EV and HEV, the power battery must capable of performing charge and discharge for longer period of time implies that longer life cycle of the battery. Hence, batteries are required to undergo cyclic battery test. However, the cyclic test is time consuming that will result in long waiting time for the test to complete. In addition of conventional battery cyclic test, it costs great expense for battery manufacturer to verify battery life cycle. Each of battery produced under same factory doesn't mean that all battery performance for particular application is all the same. Chemical reaction in each battery are varies thus affecting the battery performance.

Thus, the need for fully automated cyclic test station is appear. Therefore in this project will focus on the design and development of automation of battery cyclic tester. Microsoft Visual Basic will be used to enable automatic battery testing. As proposed, the result from this project is expected to reduce man-hour waiting time during conducting battery testing.

ABSTRAK

Kebimbangan alam sekitar disebabkan oleh pembakaran bahan api daripada kenderaan konvensional telah memacu pembangunan Kenderaan Hybrid Elektrik. Bahagian terpenting dalam Kenderaan Hybrid Elektrik ini adalah jangka hayat bateri yang mengekang daripada terhasilnya Kenderaan Elektrik yang ekonomik kerana bateri menjadi fakto kekangan utama.

Dalam Kenderaan Elektrik dan Kenderaan Elektrik Hybrid, kuasa bateri mesti mampu menjalankan process pengecasan dan dinyacas untuk jangka masa yang lama, ini mengambarkan kitaran jangka hayat operasi bateri tersebut. Maka, bateri haruslah melalui ujian kitaran bateri. Namun demikian, ujian kitaran bateri ini memakan masa maka, masa yang lama diambil untuk ujian ini selesai. Tambahan pula, ujian kitaran bateri yang konvensional melibatkan kos yang tinggi kepada pengeluar bateri untuk tujuan pengesahan. Setiap bateri yang dikeluarkan oleh kilang yang sama tidak semestinya prestasi bateri tersebut untuk aplikasi tertentu adalah sama. Tindak balas kimia dalam setiap bateri berubah maka memberi kesan kepada prestasi bateri.

Jesteru, keperluan untuk stesen ujian kitaran automatik telah muncul. Maka, projek ini berfokuskan kepada merekabentuk dan membangunkan penguji kitaran bateri automatik. Microsoft Visual Basic akan digunakan untuk membolehkan ujian kitaran bateri berjalan secara automatik. Seperti dicadangkan, hasil daripada projek ini akan mengurangkan masa manusia untuk menyelia ujian kitaran bateri ini.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will cover about introduction of "Design & Development of Automatic Battery Cyclic Tester". Background of the study is related to the battery application in Electric Vehicle field. Problem statement regarding to this project is described and thus aims the project objective to be achieved.

1.2 Background

In recent years, development in battery technologies has made possible the usage of rechargeable batteries in new systems such as in telecommunication systems, electric vehicles and so on [1]. The storage battery is the power source of electric vehicle, in order to keep the good capability of the battery pack and long usage life, some necessary administer and control for them is needed. Method to obtain the battery state of charge (SOC) accurately and reliably has become the most basic and first task, because the SOC value reflects the state of battery directly.

There are several method can be used to monitor the battery parameter which is specific gravity, open circuit voltage, load voltage and coulometric measurement [2]. Specific gravity and open circuit voltage are used to measure the state of charge however load voltage is used to measure the usable capacity [2, 3]. The last technique measures the amount of amp-hours taken out of (or put into) a battery, which can be thought of as an indirect indication of usable capacity [2]. It must be pointed out that a long time (7-8 hours) is necessary to recharge the battery, if above methods are employed. Different methods have been proposed to minimize the negative effects (mainly, a premature battery ageing) of increasing charging current

Thus, the efficiency of charging process in each case must be determined by testing. Testing batteries implies to study the evolution of battery parameters like voltage (V), current (I), temperature (T), and pressure (P), for hundreds and hundreds of charging-discharging processes [4]. In concise battery testing is a very time consuming operation and the need for a fully automated test station is appeared [5].

The battery cyclic test procedure involves the repetition process of charging and discharging the battery until a complete 500 cycles is achieved. During transaction between charging and discharging process, the battery is left rest for duration of 30 minutes to 60 minutes. Measurements regarding battery parameter and charging parameter should be taken for further analysis. Sub-topic problem statement illustrates the flow of battery cyclic test.

1.3 Problem Statements

This project focuses on developing an automatic battery tester. Figure 1.1 shows the standard procedure of cyclic battery testing. This project is done in which a Graphical User Interface (GUI) software for automation battery cyclic test is developed. In order to enable for the software to read and sent signal to the hardware equipment (charging and discharging controller) Data Acquisition System is design and programmed in the Cyclic Test GUI. Analog input channels are used to read voltage output from sensors for each battery's parameter and charging-discharging parameter. An analog output is used to send signal to the driver circuit and energizes relay that control charging and discharging switch of the battery.

Microsoft Visual Basic is identified as programming software platform to develop automation of the battery testing [11]. This programming platform provides user interface environment and easy programming language that seem identical to C++ Builder but it comes free (Visual Basic 2010 Express Edition only) from Microsoft and simple programming process through Net.Framework intellisense. While Advantech USB 4716 is chosen as DAQ device for this project due to real plug and play through USB port.

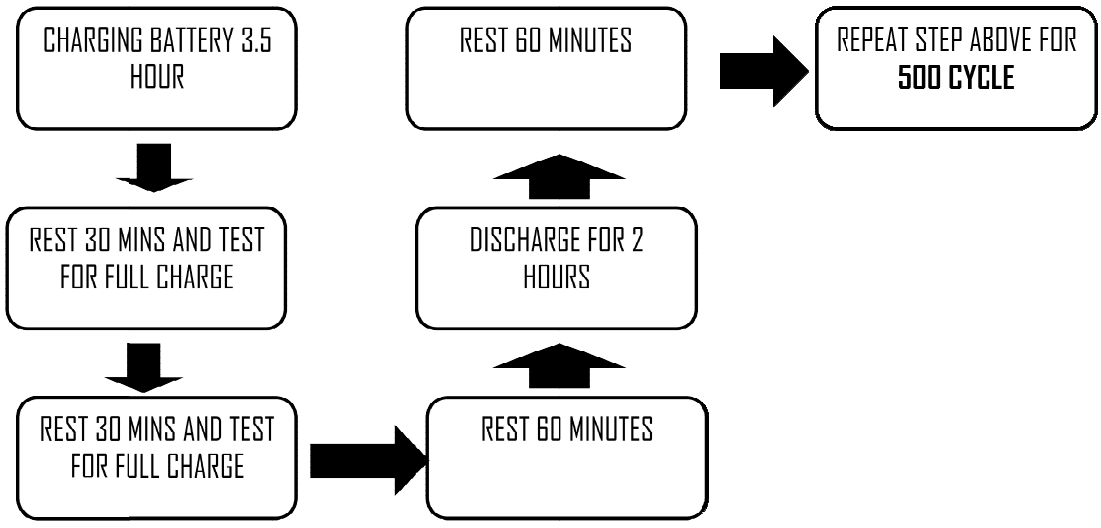

Figure 1.1: Battery Cyclic Test Flow Chart

A PC based system for testing batteries in full controlled environment has to be developed. The system must able to perform fully-automated battery cyclic test. Also, with this system all parameters involved in battery charging-discharging processes are obtained. Finally, system provides database with all sampled data. In this way, in future data processing and analysis is possible.

1.4 Research Objectives

i. Design & develop software that simulate battery cyclic test.
ii. Program the DAQ System into the developed software.
iii. Software is able to read signal from DAQ device and DAQ device can produce output signal throughout in the software to the hardware.

1.5 Research Questions

i. How to make battery cyclic tester automatic?
ii. How to create a GUI software that can read parameters of the battery and able to perform cyclic test onto the battery automatically via DAQ Card?

1.6 Scope of Research

The scope of this research is to create GUI Software that simulates battery cyclic test procedure as mention in Figure 1.1 in sub-topic Problem Statement. Microsoft Visual Basic (VB) is identified as a programming language platform tool to be used to create the software. VB is good platform for beginner and intermediate programmer to create GUI software [11]. GUI programming offers friendly and easy control to the user to supervise, monitor and authorize battery cyclic test. Real time DAQ system is programmed into the system to obtain experimental parameter. Parameters such as charging voltage, charging current, discharging current, battery voltage and battery temperature are obtained from the hardware via DAQ device. The design of DAQ system is made of Advantech USB 4716 device and the device driver is Advantech Navigator 3.0.

1.7 Significance of Study

Significance of this project is that the software that can be used to investigate life cycle performance of battery. This project can contribute in battery technology development especially in green vehicle technology.

1.8 Thesis Outline

This thesis is organized into 5 chapters and they are outlined as below:

Chapter 1 explains the introduction, background study and problem statement of Design & Develop Automatic Battery Cyclic Tester, research objective, the scope of project, significant of the study and the thesis outlines.

Chapter 2 describes the architecture used in the project. It gives a brief review of battery technology in various applications, battery cell design and theory, various battery testing methods, programming language used for developing GUI, PC Interfacing between GUI Software and DAQ device Advantech USB 4716.

Chapter 3 provides description and discussion on the design of the GUI Software and PC Interfacing of the DAQ device, Software Framework, Data Acquisition System, software simulation and Database design. This chapter intends to explain the methodology of this project.

Chapter 4 shows the results and discussions about software simulation results and finalized software design with DAQ device is programmed in the develop software.

Lastly, **chapter 5** summarizes the overall conclusion for this thesis and a few suggestion and recommendation for future development.

1.9 Conclusion

In this chapter, the problem statement of this research project is stated clearly with the help of background study. Thus, research objective and research scope can be listed properly. With all the comprehension of research framework, all in this chapter component could be used to mapping and drive this research to completion. In next chapter, the literature review of this research component will be described briefly and concise.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the literature review of research component. Project component that reflect to this research such as battery technology, battery testing method, GUI Software programming and DAQ System design are explained in term of literature review and theoretically.

2.2 Battery Invention

It is Volta who's discovered the first battery in 1800. In his research, a continuous flow of electrical force is generated when certain fluids were used as ionic conductors to promote an electrochemical reaction between two metals electrodes [9]. The basic construction of electricity storage is called voltaic cell. A battery in definition is an electrical device that capable of converting chemical energy into electrical energy and vice versa.

Lead acid battery was found by Goston Plante a France Scientist in 1859 [10]. Perhaps, it is the oldest rechargeable battery was created in human history. Since then the application for rechargeable battery is increase in various field and demand. In some way, lead acid battery can be either advantages or disadvantage regarding particular application. Nevertheless, battery is solely device that capable of storing electrical energy for portable application purpose since electrical power system cannot be reach in mobile application.

Today, the advancement in battery technology had made great contribution in humanity. Battery is widely used as power storage generated from renewable energy such as Photovoltaic (PV), Solar Energy, Wind Energy and others small scale energy. Power stored in the battery in term of chemical reaction that will produce potential difference that converts chemical reaction into electricity. Battery is widely used in UPS application, conventional vehicle, hybrid vehicle, aircraft, military, telecommunication and etc. When high security in power supply becomes an issue, in order to mitigate power interruption a particular battery type is used to provide power during blackout. Type of battery will depend on variety of battery application that requires a particular current (Amp) to be supplied into a desired load

2.3 Cell Design and Theory

Lead dioxide (PbO_2) in the positive plate, sponge lead (Pb) in negative plate and a solution sulphuric acid (H_2SO_4) in water as electrolyte are the active material in lead acid cell. The chemical reaction during discharge and recharge is normally written:

$$PbO_2 + Pb + 2\,H_2SO_4 \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} 2PbO_4 + 2H_2O$$

This reaction gives the ideal proportions by weight of the reactants to deliver capacity at a very low discharge rate when the amount of PbO_2, lead and sulphuric acid would be simultaneously depleted to zero. In practical, the reactions during discharge are not carried to completion and the theoretical capacity of reactant is never delivered.

Basically, three components must exist in battery construction; the negative electrode (cathode), positive electrode (anode) and electrolyte or known as aqueous solution that provide ionic positive and negative charge. The chemical reaction known as Oxidation-Reduction transfers charge from ions in solution to conducting electrons in the electrode.

Electrical conduction mechanism is via migration of ions via diffusion or drift that occurred within the electrolyte. Up until diffusion within electrolyte replenishes ions near electron, excess electrons are created in lead electrode (anode), and electron deficit (decrease) is created in lead-dioxide electrode (cathode). Electric field is generated at electrode surfaces and particularly opposes the flow of ions. The excess electron creates potential difference across battery terminal (Figure 2.1).

By connecting the battery to electrical power source (Figure 2.2), electrons will be forced to flow from positive to negative terminals; this will increases the charge and the voltages at the electrodes. The chemical reactions are driven in the reverse direction converting electrical energy into stored chemical energy. As the charge increases, the acid electrolyte becomes stronger.

On the other hand, when connecting the battery into external circuit (Figure 2.3) that contains load (resistance), the connection allows electrons to flow from negative to positive terminals. This reduces the charge and the voltages at the electrodes. The chemical reactions are able to proceed, generating new electrons and generating the power that is converted to electrical form to provide supply for

external electrical load. As the battery is discharged, the electrodes become coated with lead sulphate and the acid electrolyte become weaker.

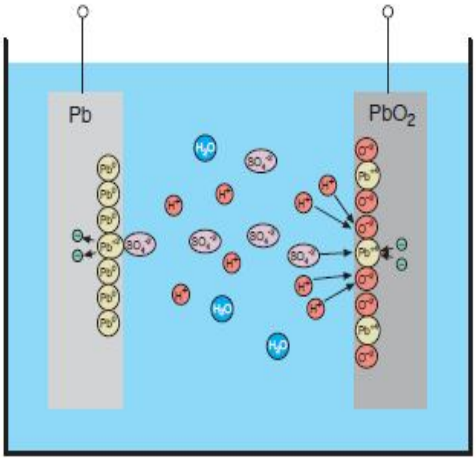

Figure 2.1: Basic battery construction without connected to external circuit

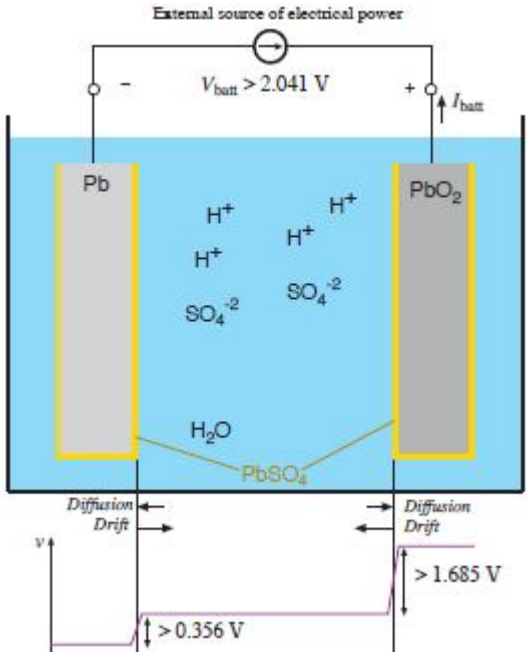

Figure 2.2: Battery is connected to external power supply (charging)

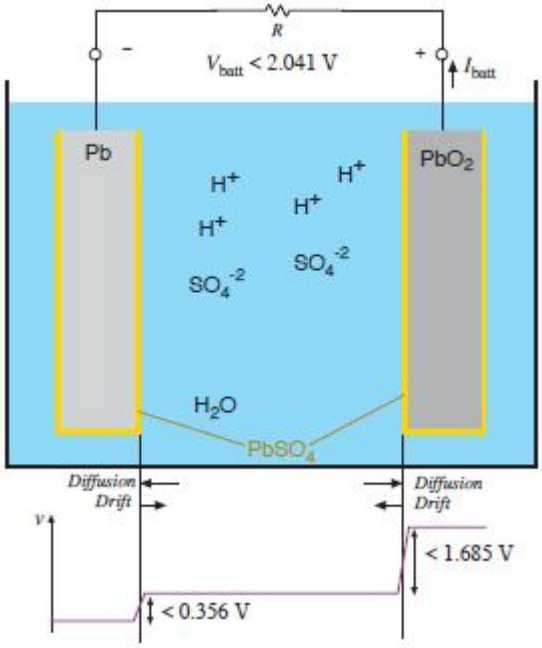

Figure 2.3: Battery is connected to external electrical load (discharging)

2.4 Battery Testing

Battery testing is carried out to obtain important information regarding the battery status. Battery testing answers technical question about state-of-charge, state-of-health, battery performance, life prediction, capacity and others important battery specification and behavior. In order to conduct several of battery testing, it is crucial to understand how battery parameter is measured. There is two type of measurement in battery testing, direct measurement and indirect measurement [9] [12].

There is few type of battery testing [13]:

- Qualification test
- Abuse test
- Cycle test
- Load test

Each test aims to seek answer of battery behavior. In this project, cycle test will be implemented on the battery to analysis life cycle of 12V lead acid battery. Cyclic test is perhaps the most important of the qualification tests. Battery is subjected to repeated charge - discharge cycles to verify that the cells meet or exceed the manufacturer's claimed cycle life. Cycle life is usually defined as the number of charge - discharge cycles a battery can perform before its nominal capacity falls below 80% of its initial rated capacity. These tests are needed to verify that the battery performance is in line with the end product reliability and lifetime expectations and will not result in excessive guarantee or warranty claims.

Temperature, charge and discharge rates, and the Depth of Discharge (DOD) each have a major influence on the cycle life of the battery [11]. Depending on the purpose of the tests, the temperature and the DOD should be controlled at an agreed reference level in order to have repeatable results which can be compared with a standard. Alternatively the tests can be used to simulate operating conditions in which the temperature is allowed to rise, or the DOD restricted, to determine how the cycle life will be affected.

Similarly cycle life is affected by over charging and over discharging and it is vital to set the correct voltage and current limits if the manufacturer's specification is to be verified. Cycle testing is usually carried out banks of cells using multi channel testers which can create different charge and discharge profiles including pulsed inputs and loads. At the same time various cell performance parameters such as temperature, capacity, impedance, output power and discharge time can be monitored and recorded. Typically it takes about 8.5 hours for a controlled full charge discharge cycle. Hence, testing up to 500 cycles will take 177 days assuming working 7 days per week 24 hours per day. Thus it takes a long time to verify the effect of any ongoing improvements made to the cells. Because the ageing process is continuous and fairly linear, it is possible to predict the lifetime of a cell from a smaller number of cycles. However to prove it conclusively in order to guarantee a product lifetime would require a large number of cells and a long time. For high power batteries this could be very expensive.

2.5 Microsoft Visual Basic

Visual Basic (VB) is a programming environment from Microsoft in which a programmer uses a graphical user interface (GUI) to choose and modify preselected sections of code written in the BASIC programming language. Visual Basic is fully object-oriented and compatible with many other languages using the .NET Framework. The VB studio Integrated Development Environment (IDE) is incredibly powerful and provided hundreds of tools for building and modifying projects. Thus provides easy platform for new beginner or intermediate personal in software programming.

Microsoft Windows uses a graphical user interface, or GUI (pronounced "gooey"). The Windows GUI defines how the various elements look and function. When create a new windows it is called as form. Then when use the toolbox to add the various elements, it is called controls. The projects that are written follow a programming technique called object-oriented programming (OOP).

2.5.1 Microsoft's Visual Studio

The latest version of Microsoft's Visual Studio, called Visual Studio 2010, includes Visual Basic, Visual C++, Visual C# (C sharp), Visual F# (F sharp), JScript, and the .NET 4 Framework.